NASA TECH BRIEF

Lewis Research Center

Low-Cost Clearance Indicator for High Speed Turbomachinery

The Problem:

In the design testing of small, high-speed turbomachinery, it is necessary to measure the actual clearance between the tips of the rotating blades and the stationary shroud over the entire operating speed and temperature range. Excessive clearance allows flow leakage between the blade tips and the shroud which penalizes aerodynamic performance. Insufficient clearance allows contact between the rotating and stationary parts which causes major damage. To establish minimum safe clearance, it is necessary to measure the actual clearance under dynamic conditions. Conventional clearance instrumentation has serious limitations for use on small, high-speed turbomachinery. The most serious of these limitations are low frequency response, large probe size, low system stability, and high unit cost.

The Solution:

A low cost clearance measuring system capable of measuring blade-to-shroud clearances of turbines and compressors operating in the speed range of 20,000 to 100,000 rpm with blade thicknesses as small as 0.750 mm (0.030 inch) and blade clearances as low as 0.050 mm (0.002 inch).

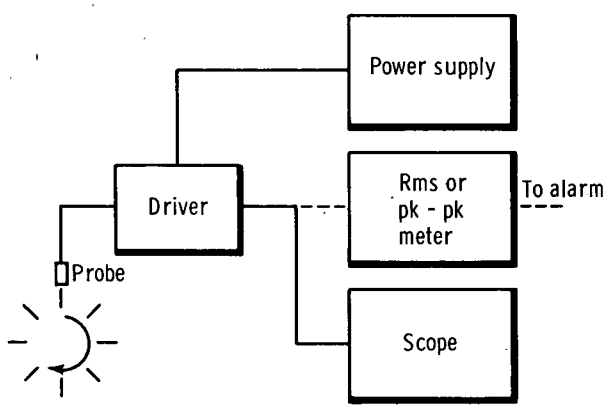

Figure 1

How It's Done:

A functional diagram of the system is shown in Figure 1. The system consists of a hermetically sealed capacitance probe, a compact electronic driver, a power supply, and an oscilloscope and/or a voltmeter for readout.

The probe, which consists of an insulated solid metal sensing element contained in a housing, is installed in an opening in the shroud in the plane of blade rotation. The face of the probe is flush with the inside circumference of the shroud. As each blade passes the probe, the capacitance formed provides an output voltage proportional to the displacement between the blade and the shroud. For calibration, probe-to-blade tip distances are set successfully with shims of known dimension in the probe mount.

A schematic of the driver is shown in Figure 2. Basically, the driver operates as an AC coupled, gain-of-one amplifier of the voltage across the probe. The dynamic voltage signal, dv/dt, is generated by the probe capacitance change, dc/dt.

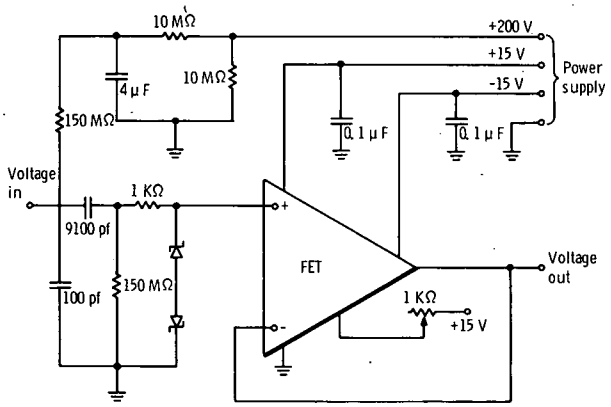

Figure 2

(continued overleaf)

$$\frac{dv}{dt} = \left(\frac{-V}{C}\right)\left(\frac{dc}{dt}\right)$$

where V is the steady state probe voltage (200 v) and C is the steady state capacitance. The 100 pf capacitor improves the low frequency response of the probe by increasing total capacitance; the 9100 pf capacitor blocks the high voltage from the amplifier input; and the zener diodes protect the amplifier from large voltage transients, especially those resulting from accidental grounding of the probe.

The output signal from the driver consists of a series of pulses, one for each blade. The height of each pulse, displayed on an oscilloscope, is a function of the distance between the blade tip and the probe.

This system requires no mechanical connection to the rotating parts of the turbomachinery, and does not disrupt the rotor mainstream flow pattern.

Notes:

1. Systems have been built and used at the Lewis Research Center that have an overall accuracy of ±0.025 mm (0.001 inch) and an operating frequency range of 10 Hz to 1 MHz, with a drift stability after warmup of ±0.005 mm (0.002 inch).
2. This system can be effectively used in other applications to measure the dynamic clearances between moving and stationary parts.
3. No additional documentation is available. Specific questions, however, may be directed to:
   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B73-10411

Patent Status:

NASA has decided not to apply for a patent.

Source: R.C. Evans, D.J. Lesco,
A.B. McLachlan and F.A. Dellatorre
Lewis Research Center
(LEW-12128)